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| **Joint Collaborative Team on Video Coding (JCT-VC)**  **of ITU-T SG 16 WP 3 and ISO/IEC JTC 1/SC 29/WG 11**  16th Meeting: San José, US, 9–17 Jan. 2014 | Document: JCTVC-P0189 |

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| *Title:* | **RCE3: Results of Subtest D.1 on Combining *N*x*2N*/*2N*x*N* Intra Block Copy with TU Process** | | |
| *Status:* | Input Document to JCT-VC | | |
| *Purpose:* | Proposal | | |
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# Abstract

HEVC Range Extensions (RExt) Core Experiment 3(RCE3) was formed to study intra block copy (IntraBC) refinement which was descripted in JCTVC-O1123, where three tools and their combination are included to be tested. This document provides the experimental results for Subtest D.1 which combines the *N*x*2N/2N*x*N* IntraBC with TU process. The average BD-rate reduction for screen contents (Class F/SC RGB444/ SC YUV444) is reported as follows:

* All-Intra: (MT) -4.0/-9.3/-9.0, (HT) -3.7/-9.3/-9.2, (SHT) -3.3/-9.1/-9.0, (Avg. Enc.) 130%, (Avg. Dec.) 100 %
* Random Access: (MT) -2.9/-7.7/-7.4, (HT) -2.7/-7.7/-7.7, (Avg. Enc.) 107 %, (Avg. Dec.) 99 %
* Low Delay B: (MT) -1.6/-5.5/-5.1, (HT) -1.6/-5.9/-5.6, (Avg. Enc.) 104 %, (Avg. Dec.) 101 %

# Introduction

At the 14th JCT-VC meeting in Vienna, the IntraBC mode is adopted in the draft HEVC Range Extension standard. Figure 1 demonstrates that the IntraBC block vector (BV) estimation for a current CU is performed by searching a match within the search range covering the reconstructed regions of the left and the current CTUs. A CU-level flag is signaled to switch adaptively between IntraBC mode and those prediction modes specified in HEVC.

To further improve the coding efficiency of the IntraBC mode, currently (a) subtest B.1 on *N*x*2N/2N*x*N* IntraBC [2], and (b) subtest B.2 on TU process [3] are being tested. The basic idea of *N*x*2N/2N*x*N* IntraBC is to perform the IntraBC mode at the PU level with the intention to find a compromise between the prediction accuracy of the IntraBC mode and the required BV overhead. Furthermore, performing IntraBC with TU process can reduce the unavailable area caused by the overlap between current CU and the reference block. The technique achieves BD-rate savings ranging from 0.0% to -15.8%, 0.0% to -13.1%, 0.0% to -12.0% for All-Intra, Random Access, and Low Delay B respectively.

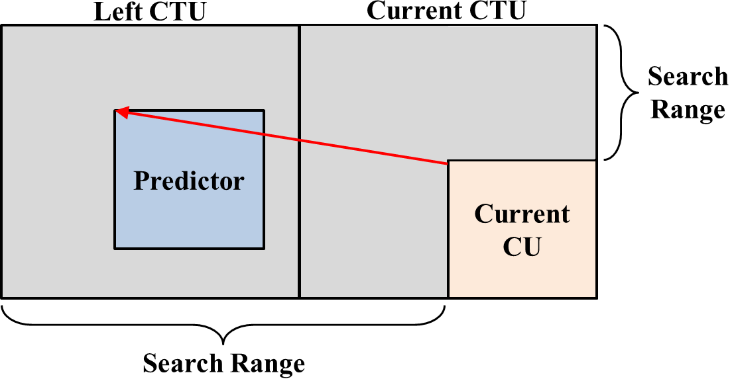


Figure 1. A demonstration of the IntraBC mode, where the gray area represents the search range of a current CU.

# *Nx2N/2NxN* Intra Block Copy with TU Process

As shown in Figure 2, the *N*x*2N/2N*x*N* IntraBC first splits a current CU of size 2*N*x2*N* equally into two PUs of size *N*x2*N* or 2*N*x*N,* which can be signaled as partition sizes following that of inter prediction modes, and predicts each PU with IntraBC. When apply TU process to *N*x*2N/2N*x*N* IntraBC, the searching area can be extended to the prior PUs within a CU.

Besides the fast encoding algorithms in the HM-12.1+RExt-5.1 software, three extra options are enabled in the current design. First, *N*x*2N/2N*x*N* IntraBC mode is evaluated only for the smallest CUs (SCUs). Second, *N*x*2N/2N*x*N* IntraBC estimation is skipped when the minimal R-D cost among all intra modes including intra prediction and IntraBC is smaller than a threshold *TH2*, where *TH2* is determined by

*TH2 = max(54, 56×Lambda)*.

Third, 2D search is skipped when the minimal R-D cost among all intra modes including intra prediction and IntraBC is smaller than a threshold *TH3*, where *TH3* is determined by

*TH3 = max(60, 64×Lambda)*.

Otherwise, the IntraSplitFlag is set equal to one once *N*x*2N/2N*x*N* IntraBC is applied.

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| (a) | (b) |

Figure 2. (a) 2*N*x*N* Intra block copy with TU process. (b) *N*x2*N* Intra block copy with TU process.

# Experimental Results

Experiments were conducted using the HM-12.1+RExt-5.1 software [3] and the RCE3 common test conditions [1] to collect the BD-rate and the encoding and decoding times of the proposed techniques in the All-Intra, Random Access, Low Delay B configurations.

1. BD-rate savings and processing time ratios of *N*x*2N/2N*x*N* intra block copy for Lossy coding.

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|  | **All Intra HE Main-tier** | | | **All Intra HE High-tier** | | | **All Intra HE Super-High-tier** | | |
| Y | U | V | Y | U | V | Y | U | V |
| Class F | -4.0% | -4.0% | -4.0% | -3.7% | -3.7% | -3.7% | -3.3% | -3.2% | -3.3% |
| Class B | 0.0% | -0.1% | -0.1% | 0.0% | -0.1% | 0.0% | 0.0% | 0.0% | 0.0% |
| RGB 4:4:4 SC | -9.3% | -9.2% | -9.3% | -9.3% | -9.3% | -9.3% | -9.1% | -9.1% | -9.1% |
| RGB 4:4:4 Animation | -0.1% | -0.2% | -0.2% | -0.1% | -0.1% | -0.1% | -0.1% | -0.1% | -0.1% |
| YCbCr 4:4:4 SC | -9.0% | -8.9% | -8.7% | -9.2% | -9.1% | -8.9% | -9.0% | -8.9% | -8.9% |
| YCbCr 4:4:4Animation | -0.1% | -0.2% | -0.2% | -0.1% | -0.2% | -0.2% | -0.1% | -0.1% | -0.1% |
| RangeExt | 0.0% | -0.1% | -0.1% | 0.0% | -0.1% | -0.1% | 0.0% | 0.0% | -0.1% |
| SC(444) GBR Optional | 11.0% | 10.7% | 10.7% | -11.8% | -11.6% | -11.5% | -12.4% | -12.0% | -11.9% |
| SC(444) YUV Optional | 13.1% | 13.1% | 12.9% | -14.6% | -14.6% | -14.3% | -15.8% | -15.4% | -15.4% |
| Enc Time[%] | 128% | | | 130% | | | 131% | | |
| Dec Time[%] | 100% | | | 100% | | | 100% | | |

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|  | **Random Access HE**  **Main-tier** | | | **Random Access HE**  **High-tier** | | |
| Y | U | V | Y | U | V |
| Class F | -2.9% | -3.4% | -3.2% | -2.7% | -3.0% | -2.9% |
| Class B | 0.0% | -0.1% | 0.1% | 0.0% | 0.0% | 0.0% |
| SC RGB 444 | -7.7% | -7.5% | -7.6% | -7.7% | -7.6% | -7.6% |
| Animation RGB 444 | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% |
| SC YUV 444 | -7.4% | -7.3% | -7.4% | -7.7% | -7.6% | -7.6% |
| Animation YUV 444 | -0.1% | -0.2% | -0.2% | -0.1% | -0.1% | -0.1% |
| RangeExt | 0.0% | 0.0% | -0.1% | 0.0% | 0.0% | -0.1% |
| SC(444) GBR Optional | -9.0% | -8.7% | -8.7% | -10.0% | -9.5% | -9.6% |
| SC(444) YUV Optional | 11.3% | 11.5% | 11.4% | -13.1% | -13.0% | -13.0% |
| Enc Time[%] | 106% | | | 107% | | |
| Dec Time[%] | 99% | | | 99% | | |

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|  | **Low delay B HE Main-tier** | | | **Low delay B HE High-tier** | | |
| Y | U | V | Y | U | V |
| Class F | -1.6% | -2.7% | -1.8% | -1.6% | -2.0% | -1.7% |
| Class B | 0.0% | 0.0% | -0.1% | 0.0% | 0.0% | 0.0% |
| SC RGB 444 | -5.5% | -5.2% | -5.3% | -5.9% | -5.5% | -5.6% |
| Animation RGB 444 | 0.0% | -0.1% | 0.0% | 0.0% | -0.1% | 0.0% |
| SC YUV 444 | -5.1% | -5.2% | -4.8% | -5.6% | -5.5% | -5.3% |
| Animation YUV 444 | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% |
| RangeExt | 0.0% | 0.0% | -0.1% | 0.0% | 0.0% | -0.1% |
| SC(444) GBR Optional | -7.3% | -6.9% | -7.0% | -8.3% | -7.7% | -7.7% |
| SC(444) YUV Optional | 10.5% | 10.5% | 10.3% | -12.0% | -12.0% | -11.8% |
| Enc Time[%] | 104% | | | 104% | | |
| Dec Time[%] | 101% | | | 101% | | |

1. BD-rate savings and processing time ratios of *N*x*2N/2N*x*N intra block copy for Lossless coding*.

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|  | **AI Main** | | | | | | | | | | | |
|  | **compression ratio (Total)** | | **compression ratio (Average)** | | **compression ratio (min)** | | **compression ratio (max)** | | Bit-rate saving (Total) | Bit-rate saving (Average) | Bit-rate saving (Min) | Bit-rate saving (Max) |
|  | Ref. | Tested | Ref. | Tested | Ref. | Tested | Ref. | Tested |
| Class F | 4.58 | 4.64 | 5.59 | 5.67 | 2.27 | 2.27 | 11.20 | 11.25 | -1.1% | -1.4% | -4.8% | -0.1% |
| Class B | 2.25 | 2.25 | 2.26 | 2.26 | 2.08 | 2.08 | 2.44 | 2.44 | 0.0% | 0.0% | 0.0% | 0.0% |
| SC RGB 444 | 9.40 | 9.76 | 11.7 | 12.49 | 6.50 | 6.62 | 19.62 | 21.77 | -3.7% | -5.1% | -11.2% | -0.1% |
| Animation RGB 444 | 2.83 | 2.83 | 2.9 | 2.86 | 2.41 | 2.41 | 3.14 | 3.14 | 0.0% | 0.0% | 0.0% | 0.0% |
| SC YUV 444 | 11.17 | 11.69 | 13.5 | 14.46 | 7.96 | 8.18 | 21.63 | 24.02 | -4.4% | -5.7% | -12.3% | -0.3% |
| Animation YUV 444 | 3.05 | 3.05 | 3.2 | 3.22 | 2.62 | 2.62 | 3.98 | 3.98 | 0.0% | 0.0% | 0.0% | 0.0% |
| RangeExt | 1.98 | 1.98 | 2.44 | 2.44 | 1.52 | 1.52 | 4.43 | 4.43 | 0.0% | 0.0% | 0.0% | 0.0% |
| SC GBR 444 Optional | 30.91 | 33.75 | 34.30 | 38.06 | 17.27 | 17.98 | 48.88 | 52.58 | -8.4% | -8.9% | -15.7% | -4.0% |
| SC YUV 444 Optional | 35.53 | 40.37 | 38.63 | 44.30 | 24.30 | 25.80 | 58.96 | 67.86 | -12.0% | -11.9% | -16.9% | -5.8% |
| Enc Time[%] | 143% | | | | | | | | | | | |
| Dec Time[%] | 100% | | | | | | | | | | | |

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|  | **RA Main** | | | | | | | | | | | |
|  | **compression ratio (Total)** | | **compression ratio (Average)** | | **compression ratio (min)** | | **compression ratio (max)** | | Bit-rate saving (Total) | Bit-rate saving (Average) | Bit-rate saving (Min) | Bit-rate saving (Max) |
|  | Ref. | Tested | Ref. | Tested | Ref. | Tested | Ref. | Tested |
| Class F | 8.64 | 8.65 | 35.85 | 36.50 | 3.01 | 3.01 | 88.86 | 91.39 | -0.1% | -0.8% | -2.8% | 0.0% |
| Class B | 2.60 | 2.60 | 2.60 | 2.60 | 2.57 | 2.57 | 2.64 | 2.64 | 0.0% | 0.0% | 0.0% | 0.0% |
| SC RGB 444 | 56.83 | 57.46 | 140.5 | 152.11 | 20.03 | 20.10 | 290.96 | 322.30 | -1.1% | -4.2% | -11.1% | -0.1% |
| Animation RGB 444 | 3.67 | 3.67 | 3.7 | 3.69 | 3.47 | 3.47 | 3.86 | 3.86 | 0.0% | 0.0% | 0.0% | 0.0% |
| SC YUV 444 | 71.01 | 71.97 | 161.3 | 174.81 | 24.73 | 24.82 | 321.23 | 356.03 | -1.3% | -4.5% | -12.0% | -0.2% |
| Animation YUV 444 | 3.87 | 3.87 | 4.5 | 4.49 | 2.79 | 2.79 | 5.70 | 5.70 | 0.0% | 0.0% | 0.0% | 0.0% |
| RangeExt | 2.14 | 2.14 | 2.57 | 2.57 | 1.59 | 1.59 | 4.50 | 4.50 | 0.0% | 0.0% | 0.0% | 0.0% |
| SC GBR 444 Optional | 70.95 | 73.64 | 329.65 | 368.08 | 19.93 | 20.51 | 498.73 | 583.22 | -3.7% | -7.8% | -14.5% | -2.9% |
| SC YUV 444 Optional | 109.02 | 115.83 | 356.47 | 417.46 | 32.52 | 33.91 | 601.48 | 702.79 | -5.9% | -11.4% | -15.6% | -4.1% |
| Enc Time[%] | 105% | | | | | | | | | | | |
| Dec Time[%] | 99% | | | | | | | | | | | |

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|  | **LB Main** | | | | | | | | | | | |
|  | **compression ratio (Total)** | | **compression ratio (Average)** | | **compression ratio (min)** | | **compression ratio (max)** | | Bit-rate saving (Total) | Bit-rate saving (Average) | Bit-rate saving (Min) | Bit-rate saving (Max) |
|  | Ref. | Tested | Ref. | Tested | Ref. | Tested | Ref. | Tested |
| Class F | 8.84 | 8.84 | 56.21 | 56.63 | 3.00 | 3.00 | 163.08 | 164.67 | 0.0% | -0.3% | -1.0% | 0.0% |
| Class B | 2.61 | 2.61 | 2.61 | 2.61 | 2.57 | 2.57 | 2.64 | 2.64 | 0.0% | 0.0% | 0.0% | 0.0% |
| SC RGB 444 | 63.65 | 64.08 | 485.60 | 529.83 | 21.03 | 21.07 | 2111.85 | 2317.23 | -0.7% | -3.9% | -10.3% | -0.1% |
| Animation RGB 444 | 3.65 | 3.66 | 3.67 | 3.67 | 3.45 | 3.45 | 3.83 | 3.83 | 0.0% | 0.0% | 0.0% | 0.0% |
| SC YUV 444 | 80.58 | 81.34 | 544.80 | 593.69 | 25.92 | 25.97 | 2333.65 | 2553.86 | -0.9% | -4.3% | -10.9% | -0.1% |
| Animation YUV 444 | 3.88 | 3.88 | 4.53 | 4.53 | 2.78 | 2.78 | 5.75 | 5.75 | 0.0% | 0.0% | 0.0% | 0.0% |
| RangeExt | 2.13 | 2.14 | 2.57 | 2.57 | 1.59 | 1.59 | 4.50 | 4.50 | 0.0% | 0.0% | 0.0% | 0.0% |
| SC GBR 444 Optional | 77.21 | 79.58 | 1334.89 | 1546.75 | 20.09 | 20.67 | 3012.92 | 3593.99 | -3.0% | -8.1% | -16.2% | -2.8% |
| SC YUV 444 Optional | 125.19 | 131.25 | 1294.26 | 1568.05 | 33.08 | 34.43 | 2516.65 | 3078.64 | -4.6% | -12.8% | -18.3% | -3.9% |
| Enc Time[%] | 105% | | | | | | | | | | | |
| Dec Time[%] | 100% | | | | | | | | | | | |

# Conclusion

In this contribution, an *N*x*2N/2N*x*N* IntraBC with TU process is proposed and tested. This scheme achieves -9.3%, and 9.2% BD-rate saving for screen content RGB 444 and YUV 444 sequences with all intra configuration respectively and keeps the syntax alignment with inter prediction modes. In view of these, we would recommend the group consider adopting the proposed mode as a part of the common test conditions and integrating it into the next release of the HM Range Extension software.

# References

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2. C. C. Chen, T. S. Chang, R. L. Liao, W. H. Peng, H. M. Hang, C. L. Lin, and F. D. Jou, "AHG8: Line-based Intra Block Copy," JCTVC-O0205, Geneva, Oct. 2013.
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4. JCT-VC, “HM-12.1+RExt-5.1,” <https://hevc.hhi.fraunhofer.de/svn/svn_HEVCSoftware/tags/HM-12.1+RExt-5.1/>

# Patent rights declaration(s)

**NCTU may have current or pending patent rights relating to the technology described in this contribution and, conditioned on reciprocity, is prepared to grant licenses under reasonable and non-discriminatory terms as necessary for implementation of the resulting ITU-T Recommendation | ISO/IEC International Standard (per box 2 of the ITU-T/ITU-R/ISO/IEC patent statement and licensing declaration form).**

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